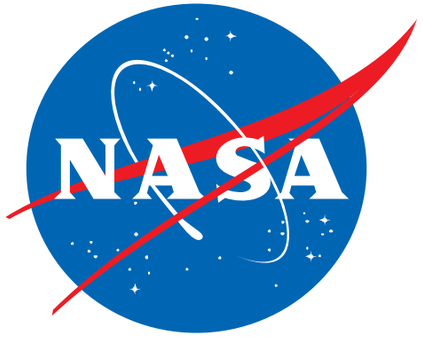


# Probabilistic Assessment of Sex-Dependent Medical Risk During Spaceflight

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# Disclosure Information

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We will not discuss off-label use and/or investigational use in this presentation

# Quantifying Risk

- Differences between males and females create different medical risks
- These differences may effect medical outcomes and mission success
- The Integrated Medical Model (IMM) was used to quantify these risks

# Sex Differences Examples

| System | Male | Female |
|---|---|---|
| Cardiovascular | Predisposition to cardiovascular events (e.g. stroke[6], MI[12]) | Higher rates of orthostatic intolerance post flight[3] |
| Genitourinary | Prostatitis[2,17] | Urinary tract conditions[7,17] |
| Musculoskeletal | Higher rates of musculoskeletal injury on ISS[19] | Osteoarthritis, joint issues[15] |
| Behavioral | Higher responses with anger, noncooperation, and conflict in psychosocial isolation[7] | Higher rates of depression and anxiety[3] |

# Study Objective

- Assess medical risk differences between men and women in a space flight environment
- Assess impact of those differences on mission outcomes
- Determine effect of those risks on different mission types/lengths
- Identify ways to mitigate risks

# What is the Integrated Medical Model?

- Probabilistic Risk Assessment (PRA) using Monte Carlo methodology
- Used to assess mission risk due to in-flight medical events
- Considers relevant preexisting medical conditions
- User defined Design Reference Missions (DRM) (e.g. crew, duration, EVA, etc.)
- Considers outcomes for 100 medical conditions that have or may occur in-flight

  Incidence data from spaceflight medical events, and analog and general populations

  ***20 of 100 conditions have sex-dependent outcomes***

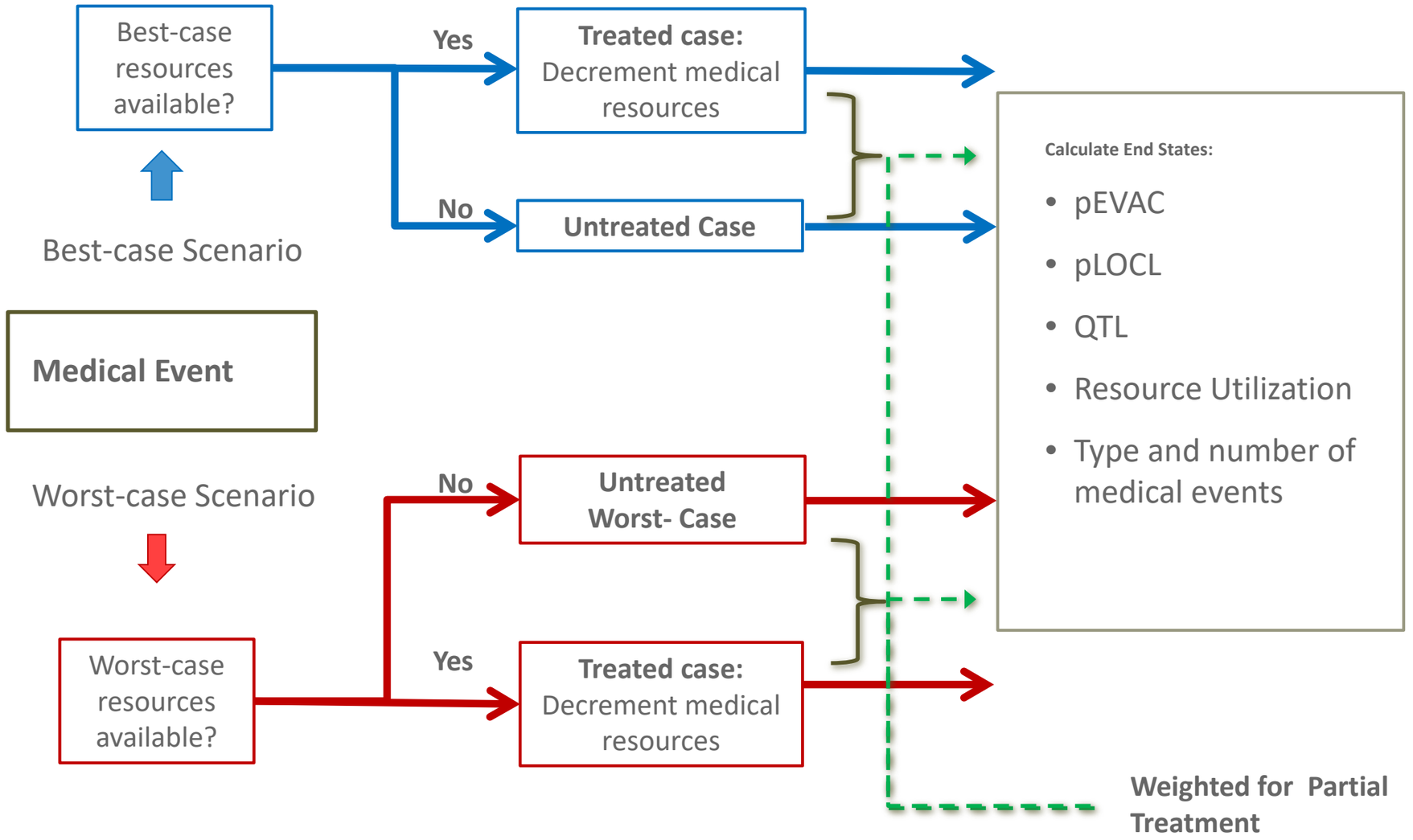
# IMM Sex-Dependent Medical Conditions

| Male Predominant | Female Predominant |
|---|---|
| Acute Prostatitis (male only) | Abnormal Uterine Bleeding (female only) |
| Acute Compartment Syndrome | Urinary Incontinence (female only) |
| Angina/MI | Vaginal Yeast Infection (female only) |
| Atrial Fibrillation/Flutter | Acute Arthritis |
| Cardiogenic Shock Secondary to MI | Acute Cholecystitis |
| Hip/Proximal Femur Fracture | Acute Glaucoma |
| Lumbar Spine Fracture | Anxiety |
| Retinal Detachment | Depression |
| Cerebral Vascular Accident | Lower Extremity Stress Fracture |
| | Urinary Retention |
| | *Urinary Tract Infection* |

# Model Outputs

- **Total Medical Events (TME)**
- **Crew Health Index (CHI)** – 0 to100%, complete impairment to normal function
- **Probability of Evacuation (pEVAC)** occurs if…
  - Risk for LOCL (needs advanced care to survive)
  - Risk for significant permanent impairment
  - Risk of intractable pain
- **Probability for Loss of Crew Life (LOCL)** – clinical scenario resulted in death
- **Influential Conditions**, those that had significant contribution to outcomes
- **Medical Resources** used

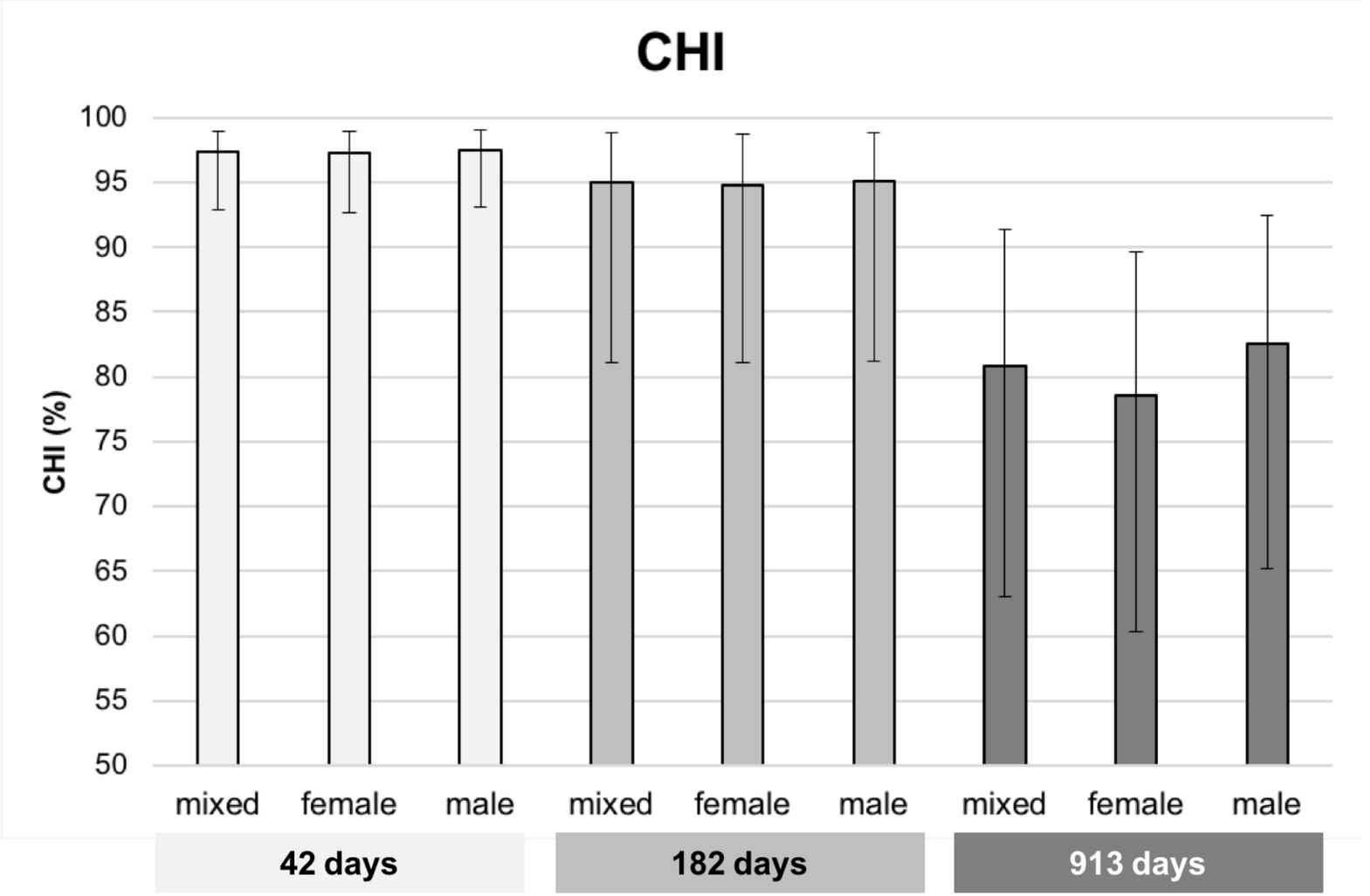
# IMM Methodology



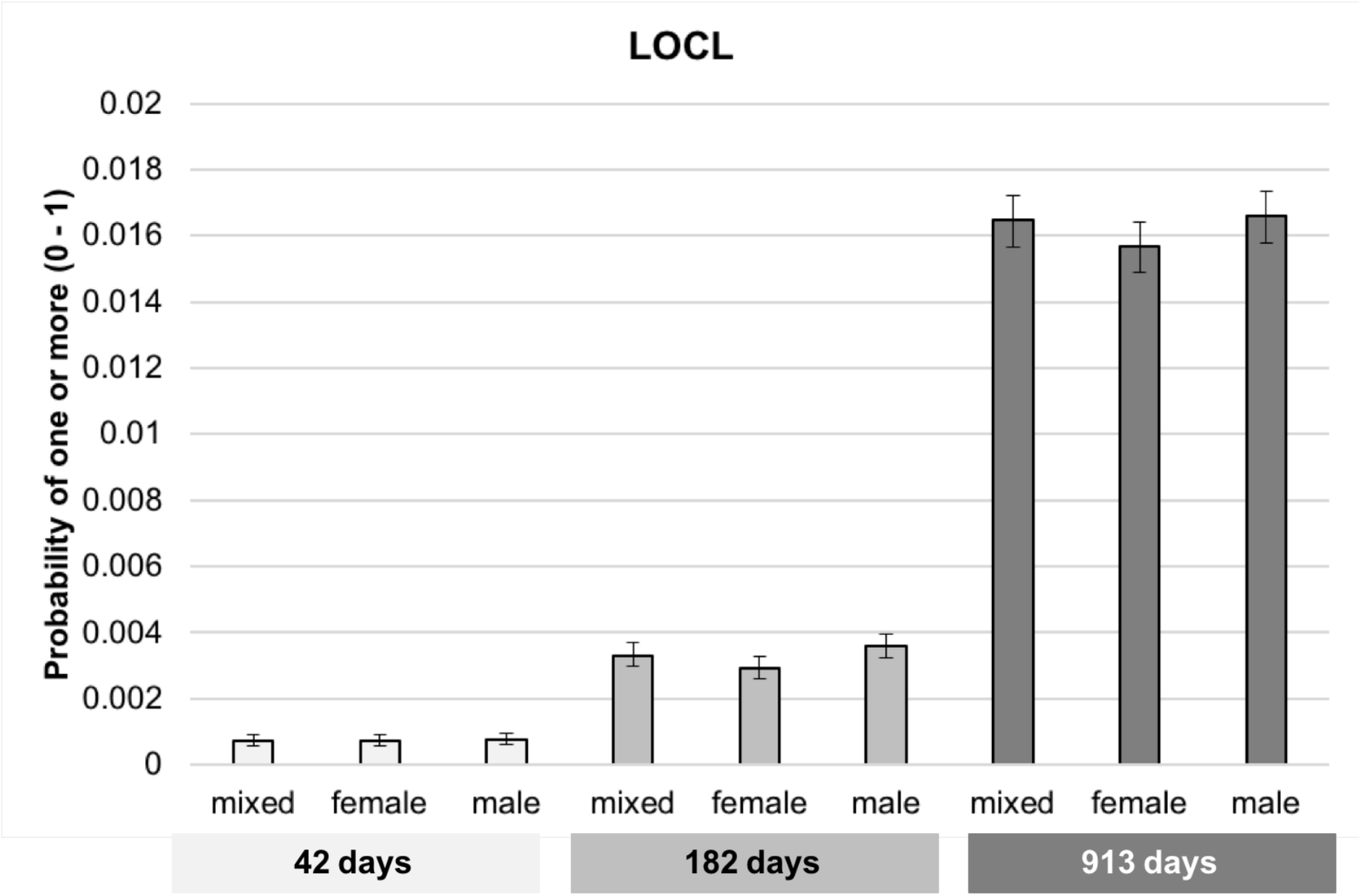
# Study Design Reference Missions (DRM)

- 4 crew members in each DRM
- Three different crews → ***mixed sex, all female, all male,***
- Three ***different mission lengths***
  - Lunar sortie (42 days)
  - International Space Station (ISS) mission (182 days)
  - Mars mission (913 days)
- 9 total studies performed
- Inventory of medical supplies from the ISS med kit **with** and **without** the possibility of resupply

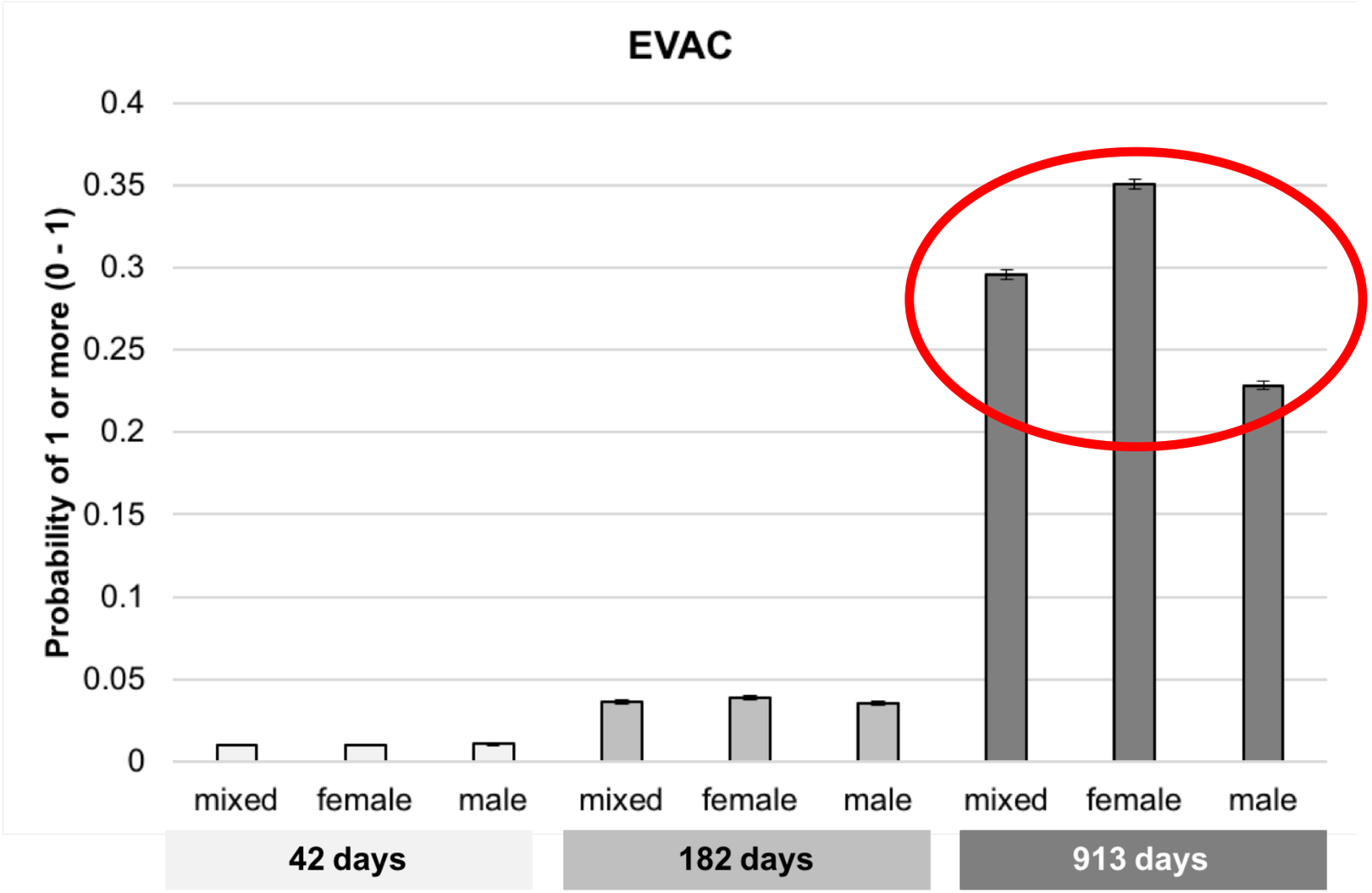
# CHI - No resupply



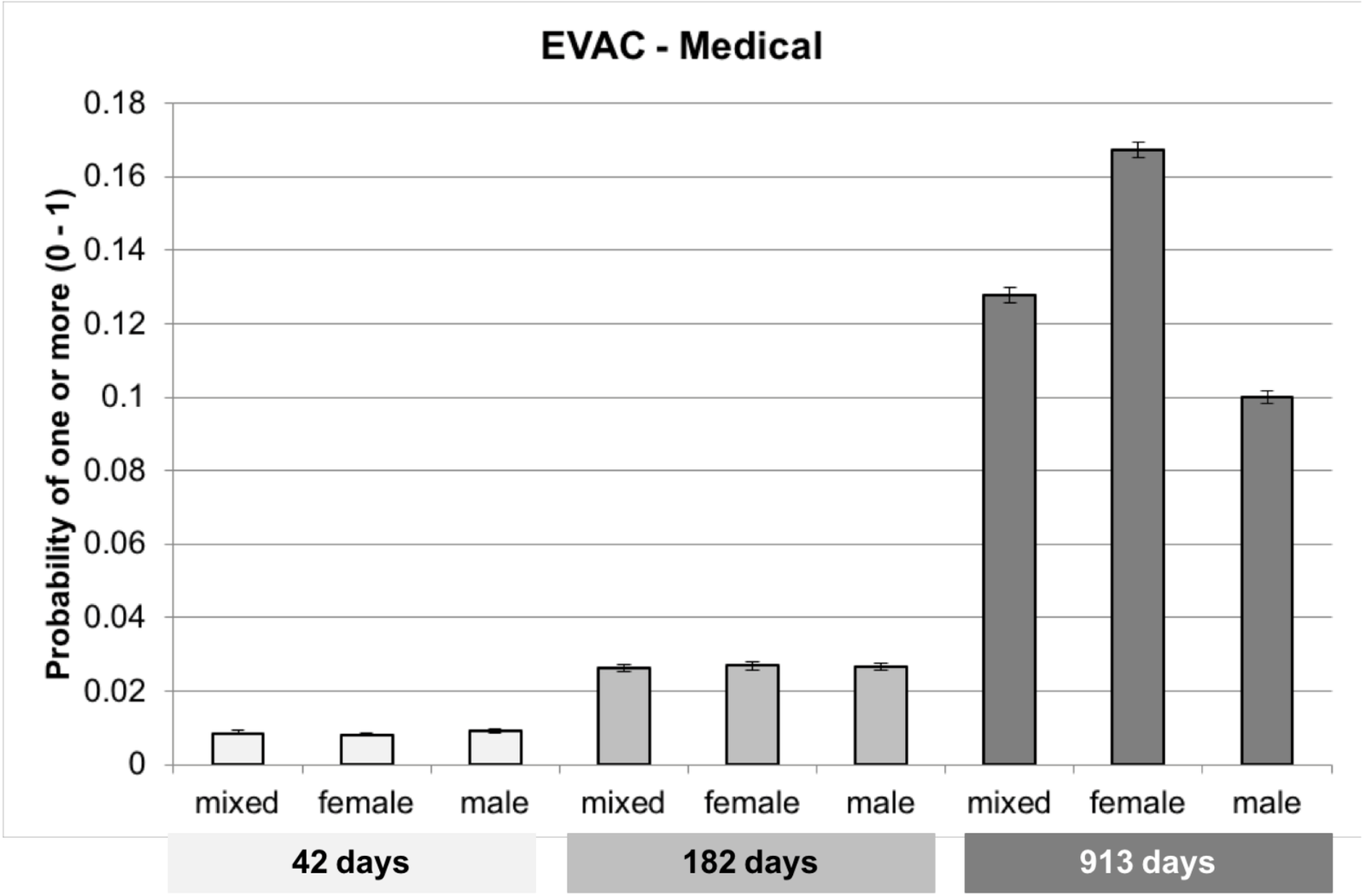
# pLOCL - No resupply



# pEVAC - No Resupply



# pEVAC Medical - No Resupply



# pEVAC (No Resupply): Female Influential Conditions

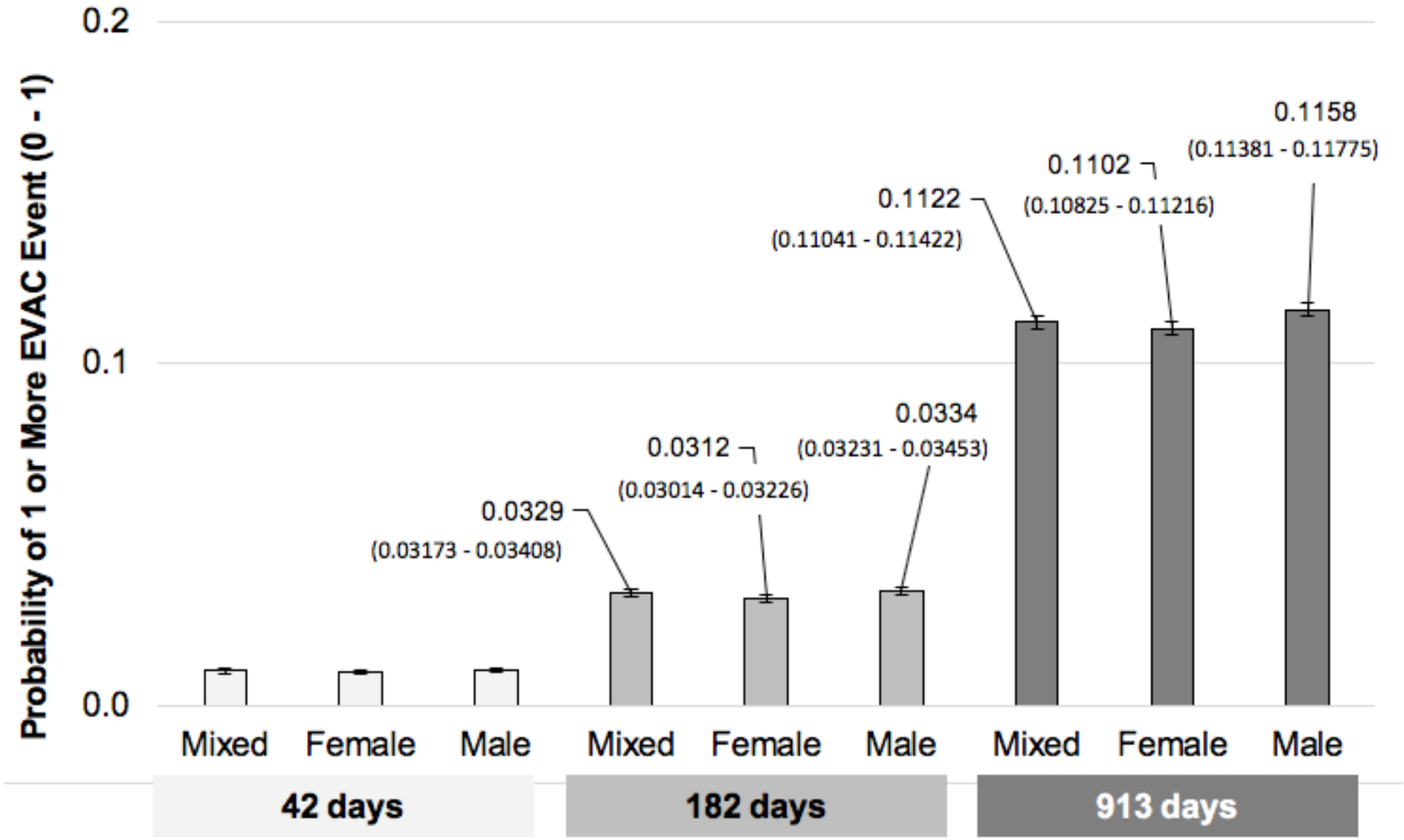
| All Female | | | | | | |
|---|---|---|---|---|---|---|
| **Rank** | **Case** | **Treated** | **Condition** | **Events** | **Contribution (%)** | **Cumulative (%)** |
| 1 | BEST | PARTIAL | EYE CHEMICAL BURN | 11702 | 28.45 | 28.45 |
| 2 | WORST | PARTIAL | URINARY TRACT INFECTION | 7710 | 18.74 | 47.19 |
| 3 | WORST | PARTIAL | BACK SPRAIN/STRAIN | 2088 | 5.08 | 52.27 |
| 4 | WORST | PARTIAL | EYE CHEMICAL BURN | 1877 | 4.56 | 56.83 |
| 5 | BEST | PARTIAL | FINGER DISLOCATION | 1527 | 3.71 | 60.54 |
| 6 | WORST | PARTIAL | NEPHROLITHIASIS | 1124 | 2.73 | 63.28 |
| 7 | WORST | TREATED | SANS | 1026 | 2.49 | 65.77 |
| 8 | WORST | TREATED | SMOKE INHALATION | 668 | 1.62 | 67.39 |
| 9 | WORST | PARTIAL | EYE INFECTION | 617 | 1.50 | 68.89 |
| 10 | WORST | PARTIAL | LE STRESS FRACTURE | 534 | 1.30 | 70.19 |

# pEVAC (No Resupply): Male Influential Conditions

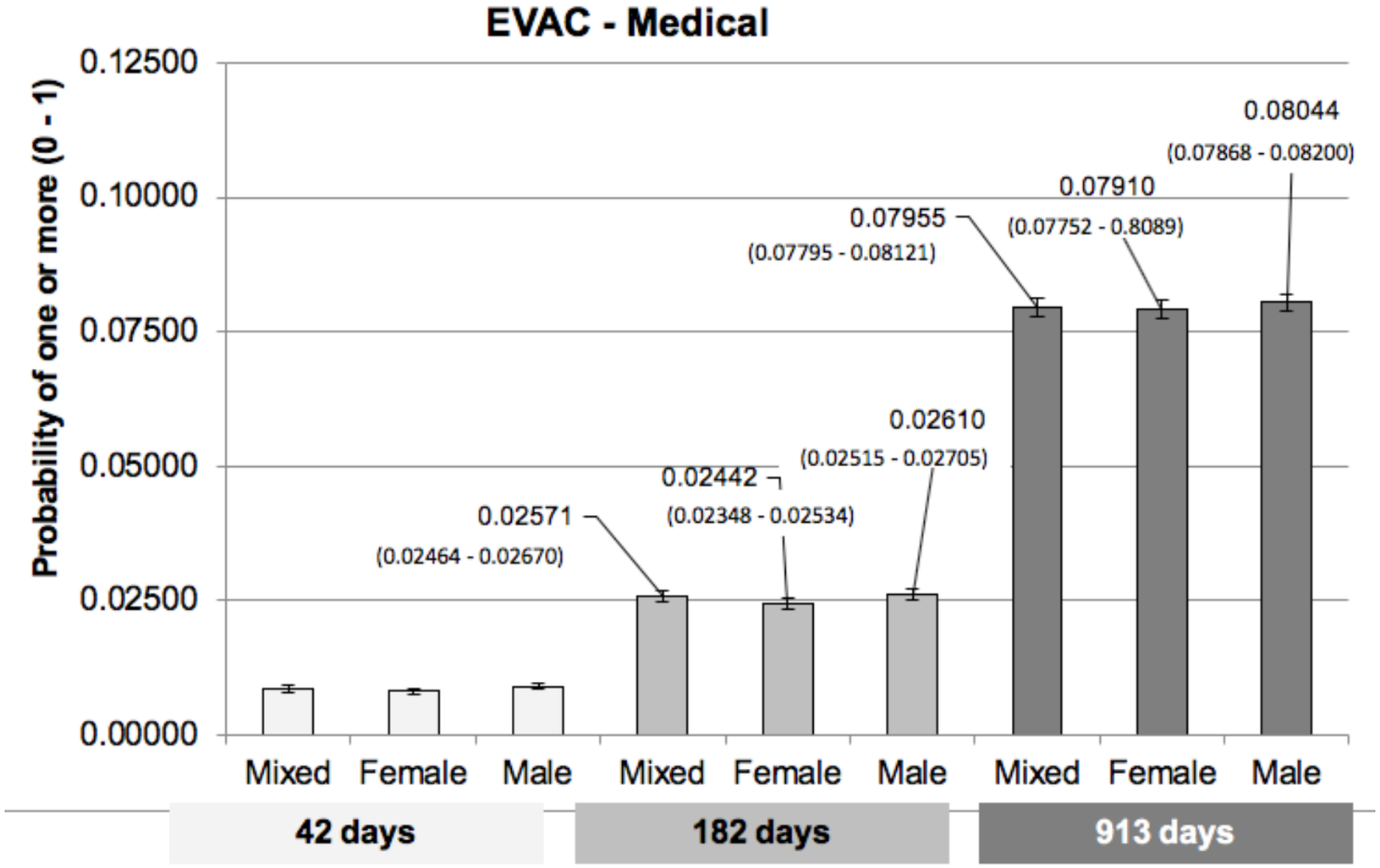
| All Male | | | | | | |
|---|---|---|---|---|---|---|
| **Rank** | **Case** | **Treated** | **Condition** | **Events** | **Contribution (%)** | **Cumulative (%)** |
| 1 | BEST | PARTIAL | EYE CHEMICAL BURN | 4072 | 16.08 | 16.08 |
| 2 | WORST | PARTIAL | BACK SPRAIN/STRAIN | 2033 | 8.03 | 24.10 |
| 3 | BEST | PARTIAL | FINGER DISLOCATION | 1603 | 6.33 | 30.43 |
| 4 | WORST | TREATED | SANS | 1022 | 4.03 | 34.47 |
| 5 | WORST | PARTIAL | EYE CHEMICAL BURN | 925 | 3.65 | 38.12 |
| 6 | WORST | PARTIAL | NEPHROLITHIASIS | 811 | 3.20 | 41.32 |
| 7 | WORST | TREATED | NEPHROLITHIASIS | 689 | 2.72 | 44.04 |
| 8 | WORST | TREATED | SMOKE INHALATION | 674 | 2.66 | 46.70 |
| 9 | WORST | PARTIAL | EYE INFECTION | 659 | 2.60 | 49.30 |
| 10 | WORST | PARTIAL | DENTAL ABSCESS | 482 | 1.90 | 51.21 |

# But…

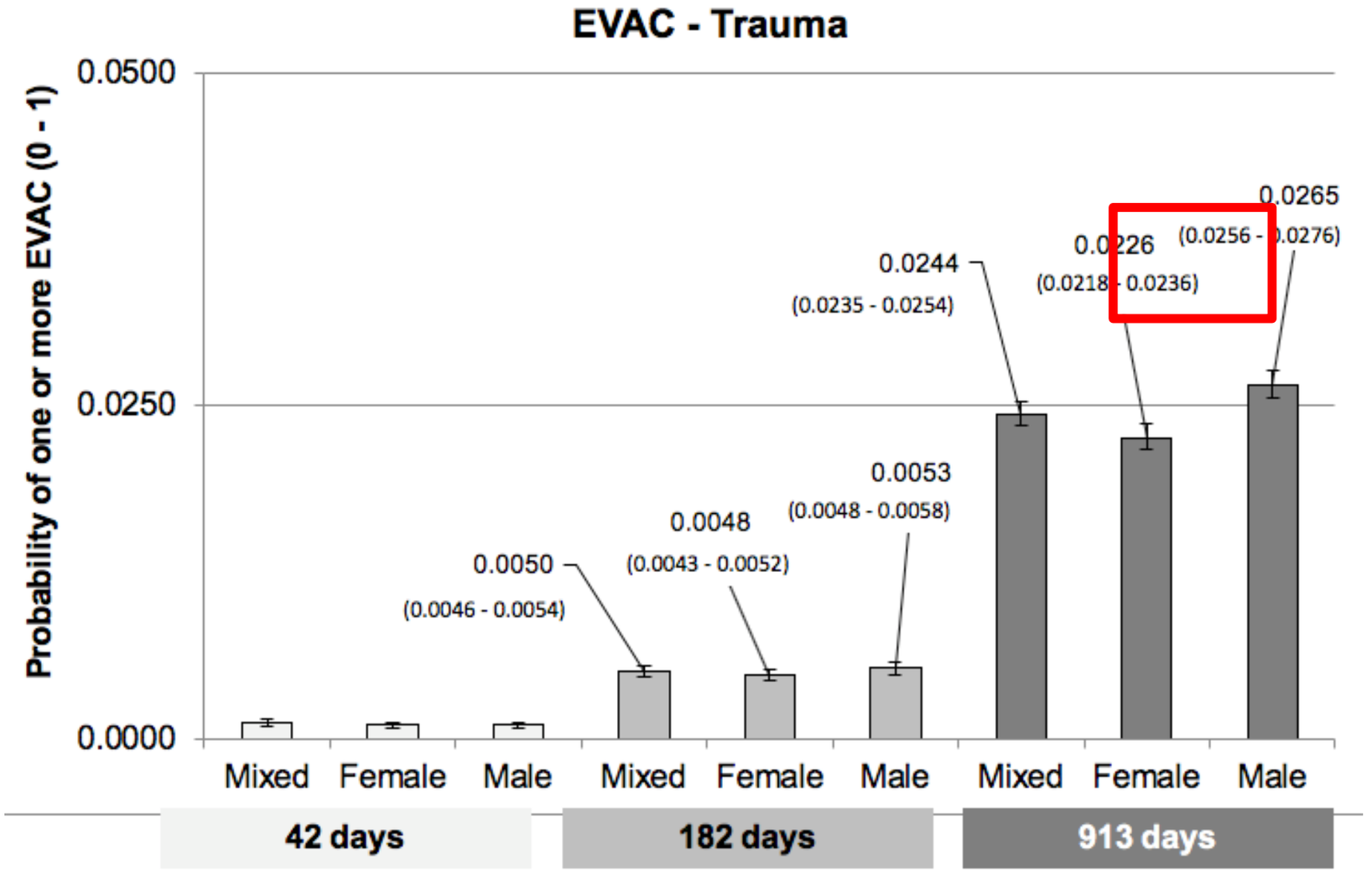
# pEVAC - With Resupply



# pEVAC Medical – With Resupply



# pEVAC Trauma – With Resupply



# pEVAC (With Resupply): Female Influential Conditions

| All Female | | | | | | |
|---|---|---|---|---|---|---|
| **Rank** | **Scenario** | **Treated** | **Condition** | **Events** | **Contribution (%)** | **Cumulative (%)** |
| 1 | WORST | TREATED | NEPHROLITHIASIS | 1490 | 12.95 | 12.95 |
| 2 | WORST | TREATED | SANS | 1074 | 9.33 | 22.28 |
| 3 | WORST | TREATED | DENTAL ABSCESS | 924 | 8.03 | 30.31 |
| 4 | WORST | TREATED | SEPSIS | 770 | 6.69 | 37.00 |
| 5 | WORST | TREATED | SMOKE INHALATION | 726 | 6.31 | 43.31 |
| 6 | BEST | TREATED | SMALL BOWEL OBSTRUCTION | 519 | 4.51 | 47.82 |
| 7 | WORST | TREATED | WRIST FRACTURE | 441 | 3.83 | 51.66 |
| 8 | WORST | TREATED | BACK SPRAIN/STRAIN | 336 | 2.92 | 54.58 |
| 9 | WORST | TREATED | URINARY TRACT INFECTION | 305 | 2.65 | 57.23 |
| 10 | WORST | TREATED | HEAD INJURY | 249 | 2.16 | 59.39 |
| 11 | BEST | TREATED | CEREBROVASCULAR ACCIDENT | 245 | 2.13 | 61.52 |
| 12 | WORST | TREATED | TRAUMATIC HYPOVOLEMIC SHOCK | 236 | 2.05 | 63.57 |
| 13 | BEST | TREATED | SEIZURES | 236 | 2.05 | 65.62 |
| 14 | WORST | TREATED | CEREBROVASCULAR ACCIDENT | 221 | 1.92 | 67.54 |
| 15 | BEST | TREATED | ANGINA /MYOCARDIAL INFARCTION | 190 | 1.65 | 69.19 |

# pEVAC (With Resupply): Male Influential Conditions

| All Male | | | | | | |
|---|---|---|---|---|---|---|
| Rank | Scenario | Treated | Condition | Events | Contribution (%) | Cumulative (%) |
| 1 | WORST | TREATED | NEPHROLITHIASIS | 1507 | 12.45 | 12.45 |
| 2 | WORST | TREATED | SANS | 1058 | 8.74 | 21.18 |
| 3 | WORST | TREATED | DENTAL ABSCESS | 803 | 6.63 | 27.82 |
| 4 | WORST | TREATED | SEPSIS | 794 | 6.56 | 34.37 |
| 5 | WORST | TREATED | SMOKE INHALATION | 734 | 6.06 | 40.44 |
| 6 | BEST | TREATED | SMALL BOWEL OBSTRUCTION | 497 | 4.10 | 44.54 |
| 7 | WORST | TREATED | WRIST FRACTURE | 463 | 3.82 | 48.36 |
| 8 | WORST | TREATED | HIP/PROXIMAL FEMUR FRACTURE | 383 | 3.16 | 51.53 |
| 9 | WORST | TREATED | CEREBROVASCULAR ACCIDENT | 340 | 2.81 | 54.34 |
| 10 | WORST | TREATED | BACK SPRAIN/STRAIN | 326 | 2.69 | 57.03 |
| 11 | BEST | TREATED | CEREBROVASCULAR ACCIDENT | 323 | 2.67 | 59.70 |
| 12 | BEST | TREATED | ANGINA/MYOCARDIAL INFARCTION | 290 | 2.40 | 62.09 |
| 13 | WORST | TREATED | TRAUMATIC HYPOVOLEMIC SHOCK | 264 | 2.18 | 64.27 |
| 14 | BEST | TREATED | ATRIAL FIBRILLATION/ FLUTTER | 263 | 2.17 | 66.44 |
| 15 | BEST | TREATED | SEIZURES | 240 | 1.98 | 68.43 |

# Discussion

- No differences in CHI or LOCL between sexes
- Partially-treated UTI drives higher female EVAC using the base ISS med kit
- Coronary and trauma risks for males are important for long missions
- Appropriate med kit design and prevention can mitigate sex-dependent risks
- Other conditions have sex-dependent risks which are not represented
- PRA is a useful tool to ask “what if…”!

# Disclaimer

These results are subject to the biases inherent in the model and should only be used by subject matter experts as one point of information among many.

**Thank you!**

*“All models are wrong. Some are useful.”*

*- George Box (1919 – 2013)*

# Back Up

# Other Considerations: Landing/Postflight

- Orthostatic intolerance
- Landing impact trauma
- Neurosensory
  - Men: higher incidence of post-flight motion sickness
  - Women: higher incidence of post-flight vestibular instability symptoms

# Other Considerations: Landing/Postflight

- Orthostatic intolerance
- Landing impact trauma
- Neurosensory[16]
  - Men: higher incidence of post-flight motion sickness
  - Women: higher incidence of post-flight vestibular instability symptoms

# Other Considerations: Behavioral/Social

- Response to stress due to psychosocial isolation[7]
  - Women: more likely to be interpersonally supportive
  - Men: more often respond with anger, noncooperation and conflict
- Inconclusive studies in spaceflight and Antarctic groups as to ideal crew composition[7,8,10,28]

# Other Considerations: Malignancy

- Women have increased susceptibility to radiation induced cancer [9]
- Antarctic winter-overs as analogue: multiple instances of cancer
- Large induction period for many cancers, but still possible for cancer to surface
  - Breast, lung, testicular carcinoma[1,2]
- Evacuation unlikely

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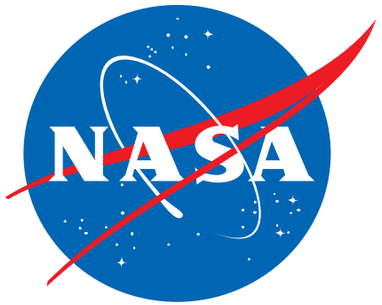
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